Space-base DTN using a Commercially Operational Low Earth Orbiting Satellite

Satellite Communication 101 (or maybe 1.01)

- The United Kingdom -Disaster Monitoring Constellation (UK-DMC) satellite is an imaging satellite
  - One of 5 (or 6 or 7 as constellation grows)
  - Commercial Money Making Operation
    - *You* can request an image (and pay)
- Polar Orbit approximately once every 100 minutes
- Satellite is in view of any one ground station for 8 to 14 minutes – hence disruption.
- Round Trip Time Delay is ~ 100 msec, thus delay is not the issue here (unlike for deep space).

UK-DMC Characteristic

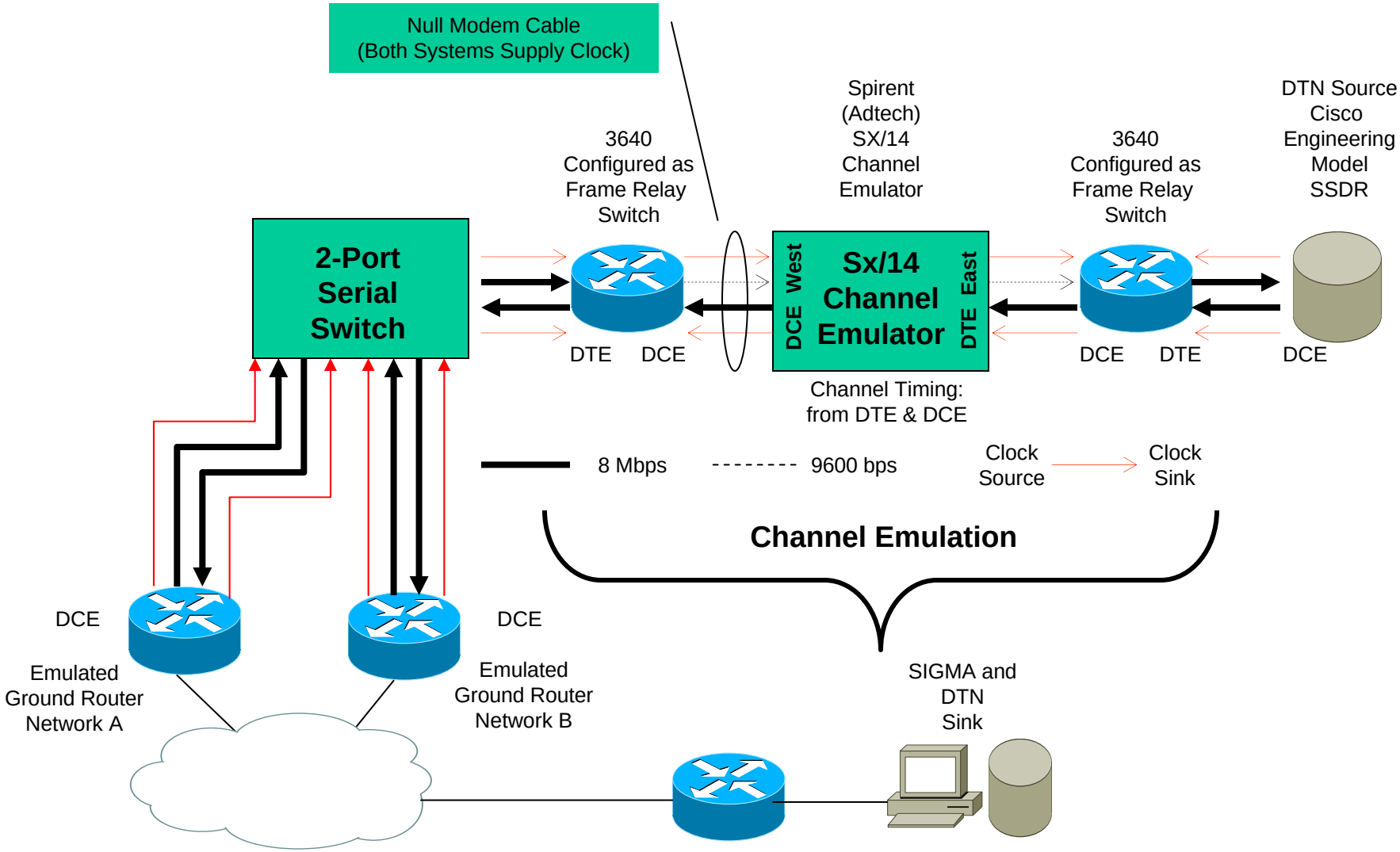
- Onboard experimental Payload, Cisco router in Low Earth Orbit (CLEO)
  - Not Used for DTN Testing
- Three Solid State Data Recorders
  - 1 with a StrongARM Processor
  - 2 with Motorola MPC8260 PowerPC (We use one of these)
    - RTEMS operating system (POSIX API, BSD sockets)
    - Storage Capacity 1 GByte RAM
    - Operating System Image limit is 1 Mbyte
- Uplink is 9600 bits per second
- Downlink is 8.134 Mbps
- Datalink – Frame Relay/HDLC
- Network Protocol – IPv4 (could easily run IPv6)
- Transport Protocol (Saratoga version 0 over UDP)
  - Saratoga version 0 is existing SSTL transport
  - Saratoga version 1 is what is in the Internet Drafts
    - Enhances version 0 to make it more widely usable

Costs

- If DTN code upload DOES NOT disrupt SSTL normal operations
  - ***$Y US*** per pass to SSTL
- If DTN code upload disrupts SSTL normal operations
  - Approximately ***10 times $Y US*** per 24 hours
- For general use, UK-DMC
  - Satellite cost is ***$Y US*** per pass
- If one uses other ground stations such as Universal Space Networks (USN), cost is:
  - ***$Y US*** per pass to SSTL
  - approximately $700 per pass to USN

Thus, Ground-based Testing is extremely Important.

DTN Testbed


Null Modem Cable
(Both Systems Supply Clock)
3640
Configured as
Frame Relay
Switch
Spirent
(Adtech)
SX/14
Channel
Emulator
3640
Configured as
Frame Relay
Switch
DTN Source
Cisco
Engineering
Model
SSDR
2-Port
Serial
Switch
DCE West
Sx/14
Channel
Emulator
DTE East
DTE
DCE
DCE
DTE
DCE
Channel Timing:
from DTE & DCE
8 Mbps
9600 bps
Clock
Source
Clock
Sink
Channel Emulation
DCE
DCE
Emulated
Ground Router
Network A
Emulated
Ground Router
Network B
SIGMA and
DTN
Sink

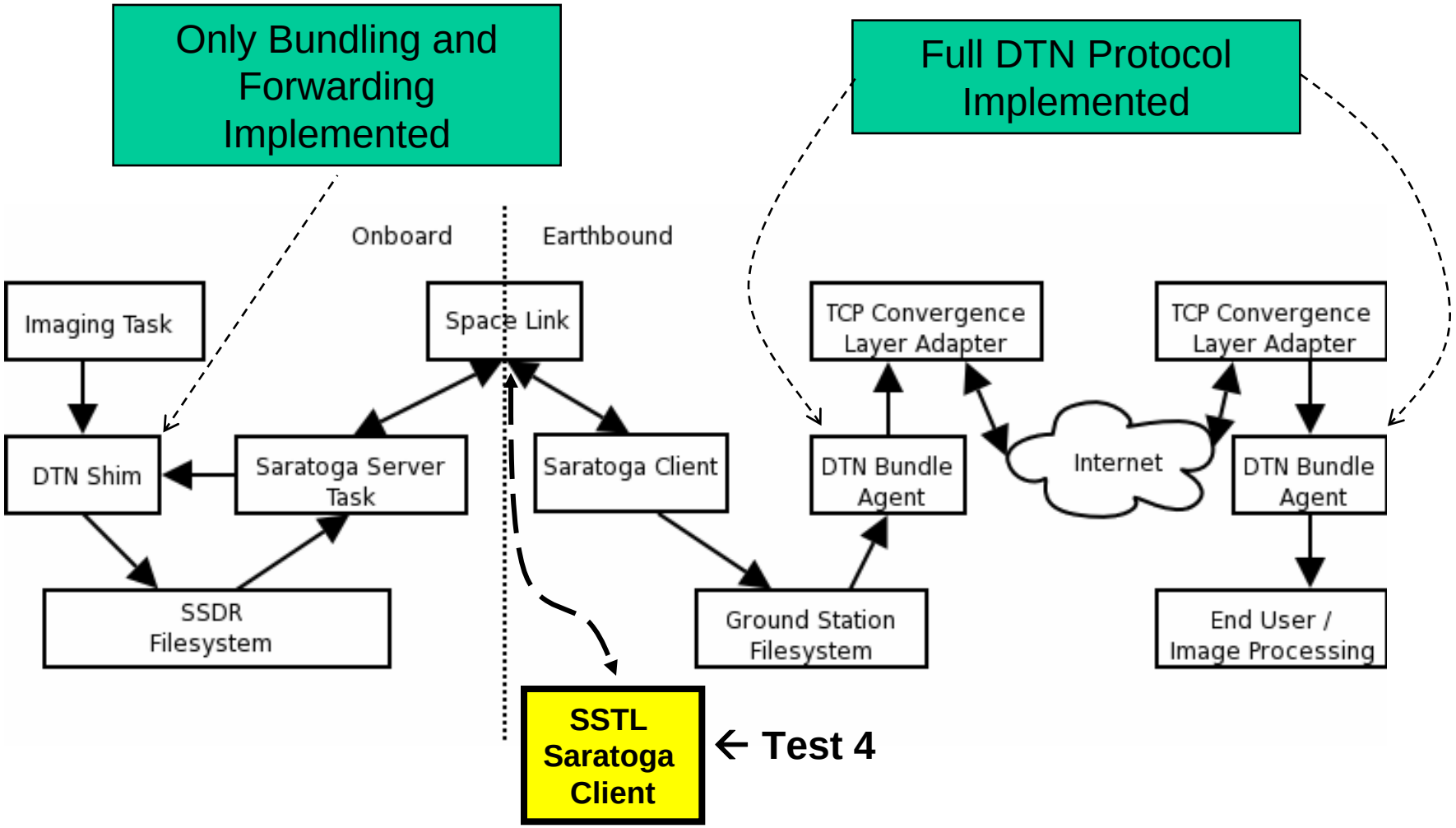
Number of Possible Tests per Pass

Description	Units					
Pass time	min	8	9	10	11	12
Pass time	seconds	480	540	600	660	720
Image Size (Mbytes)	Mbytes	160	160	160	160	160
Fragment Size (Mbytes)	Mbytes	80	80	80	80	80
Number of Fragments	GCI	2	2	2	2	2
Downlink Line Rate	Mbps	8	8	8	8	8
Test1: Saratoga full file Transfer Test	seconds	160	160	160	160	160
Test 2: DTN full Bundle Transfer	seconds	160	160	160	160	160
Test 3: Saratoga Proactive Fragmentation Transfer	seconds	160	160	160	160	160
Number of Tests Completed		3	3.375	3.75	4.125	4.5
Number of bundles that can be transferred in test 3		2	2.75	3.5	4.25	5

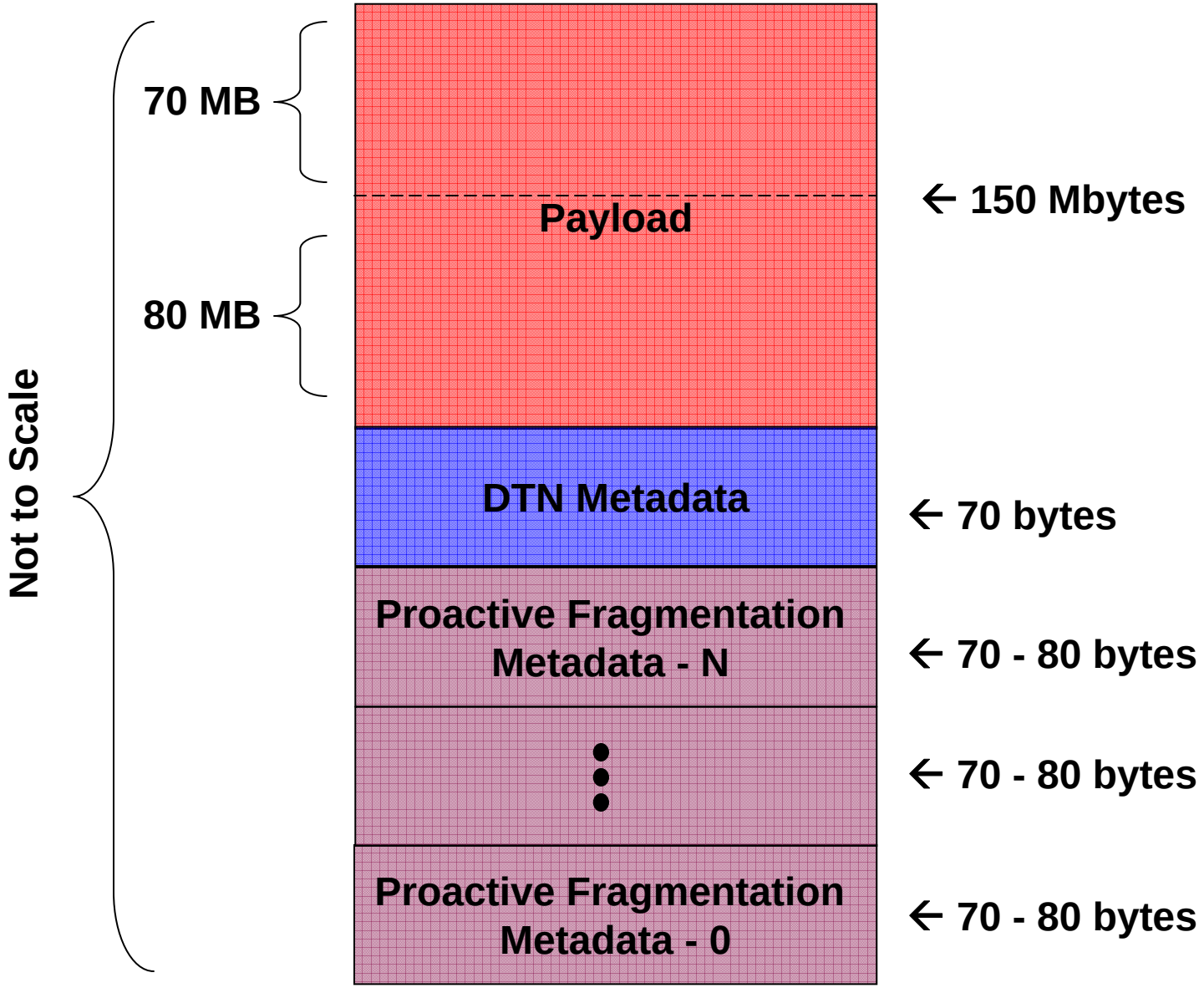
DTN Test Plan

- Goal
  - Demonstrate DTN Bundle Transfer from UK-DMC to SSTL Ground Station
  - Demonstrate that DTN code and general SSTL code can coexist without affecting normal SSTL Operations
    - Reduces costs from ***10 times $Y*** per 24 hours to ***$Y*** per pass
- Configuration
  - UK-DMC acquired a150 Mbyte image over the Gulf of Khambhat, India at ~04:35 UTC on 25 January 2008.
  - DTN bundling code default set to 80 Mbytes for proactive fragmentation
- Tests
  1. Basic file download using existing technique (GRC implementation of Saratoga version 0)
  2. Same file downloaded but treated as single bundle (DTN)
  3. Same file download but using DTN proactive fragmentation with 80 Mbytes preconfigured fragments.
  4. SSTL used their Workstation and SSTL implementation of Saratoga version 0

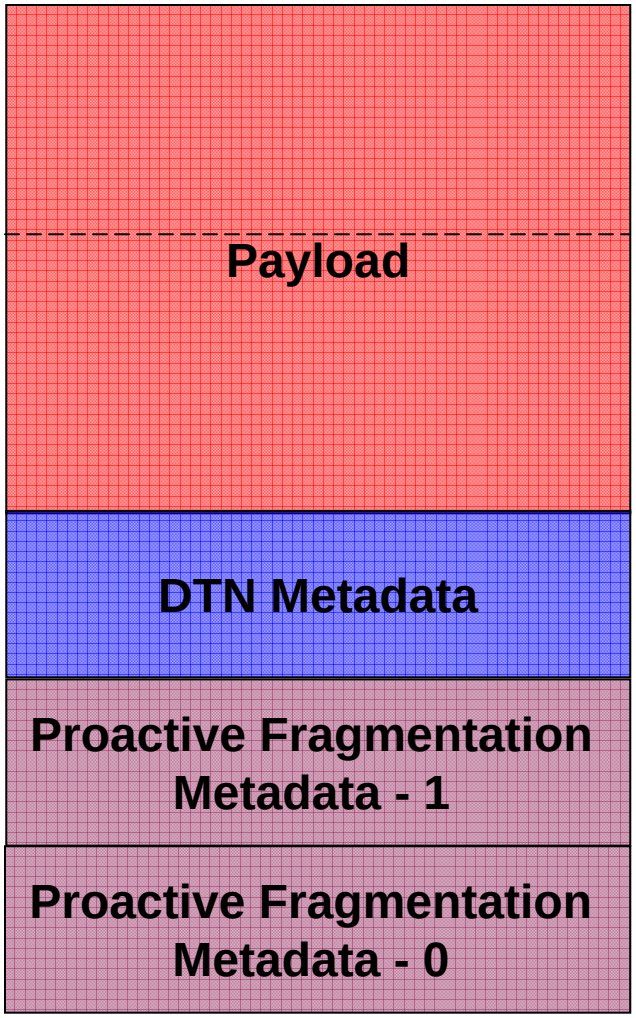
UK-DMC Implementation



Bundles on UK-DMC



File Names



DU000c76pm

← DU000c76pm.dtn

← DU000c76pm.79999999-153700328.dtn

← DU000c76pm.0-79999999.dtn

DTN Test Results

- Test 1 - Image file DU00076pm was received using GRC Saratoga version 0 implementation
- Test 2 - DTN file and associated metadata for the full bundle was received by Bundling-SSTL and then forwarded as a full bundle to Bundinging-GRC1
- Test 3 – Proactive Fragmentation:
  - The 1st proactive fragmented bundle from the UK-DMC and it was automatically transferred using DTN-2 between Bundling-SSTL to Bundling-GRC1.
  - The 2nd proactive fragmentation bundle was not retrieved
    - The directory and the syslog file showed creation of the 1st fragmentation metadata file, but not the second.
    - Analysis showed SSTL operating system limits file names to 32 characters.
- Test 4 – SSTL downloaded 150 Mbyte image cleanly
- Post Test analysis
  - Reconstructed DTN bundle payload and image file (tests 1 and 2) did not match
    - Bug found in GRC Saratoga Implementation of “Holes to fill” (we did not request retransmissions properly)

Lessons Learned

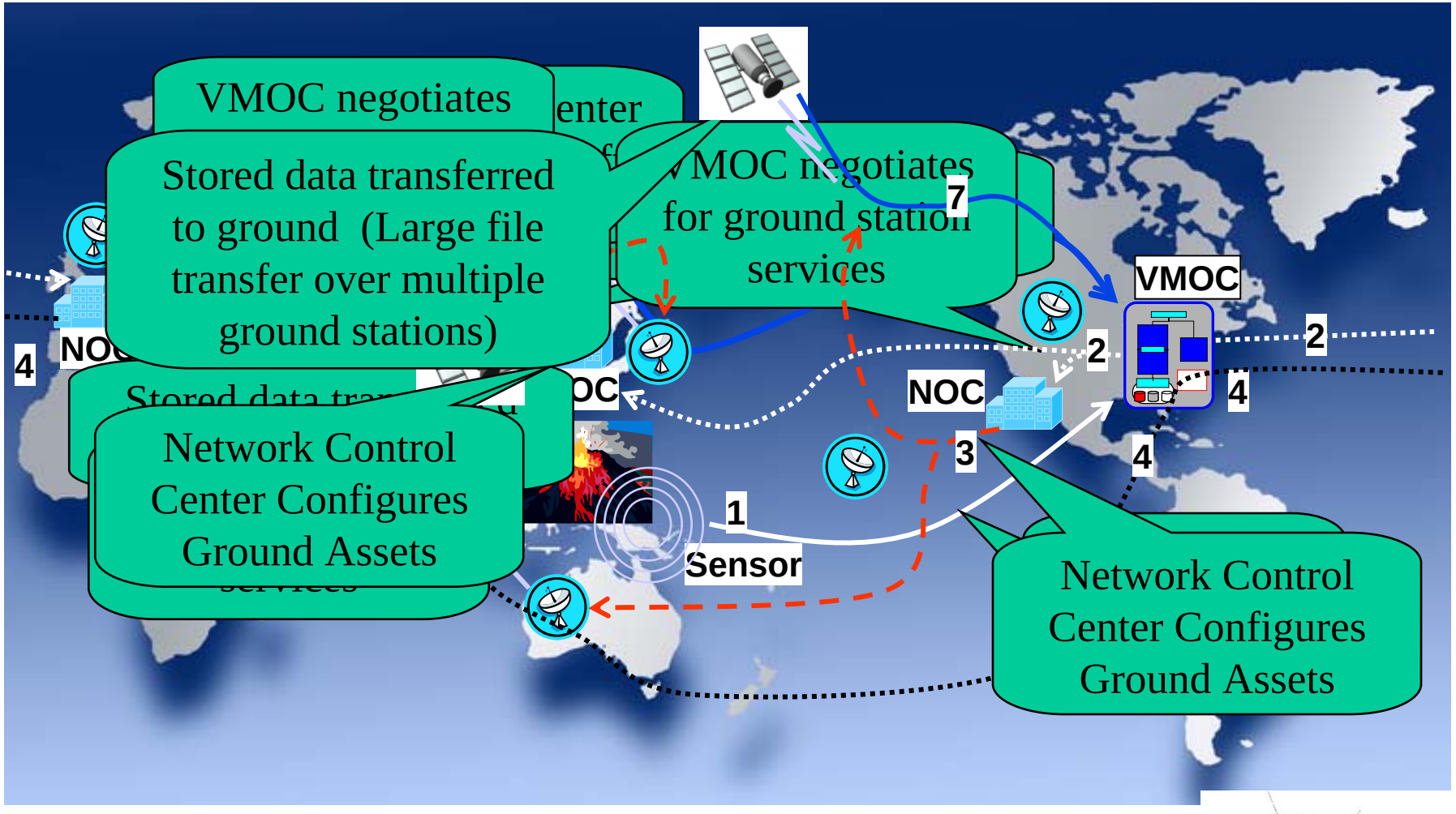
- "Holes to fill" bug would have been caught with checksums (reliability check)
- Improve ground-based testing to hopefully avoid future problems
  - Error generation was not turned on as BER system was out of the loop for a while during testbed debugging – one of a kind system is temperamental .... sometimes
- Time Synchronization is critical
  - Test time synchronization of all DTN nodes prior to testing
  - DTN expiration timer is 3 days
    - Requires image to be taken within 3 days of download.
  - Perhaps current DTN requirement for time synchronization should be reconsidered.
    - Perhaps decrement time on hop-by-hop to avoid loops
    - Perhaps time synchronization optional?
    - Not all DTN nodes may be able to do time synchronization.

How does DTN fit into a Low Earth Orbit Space Network?
"Operationally Responsive Space"

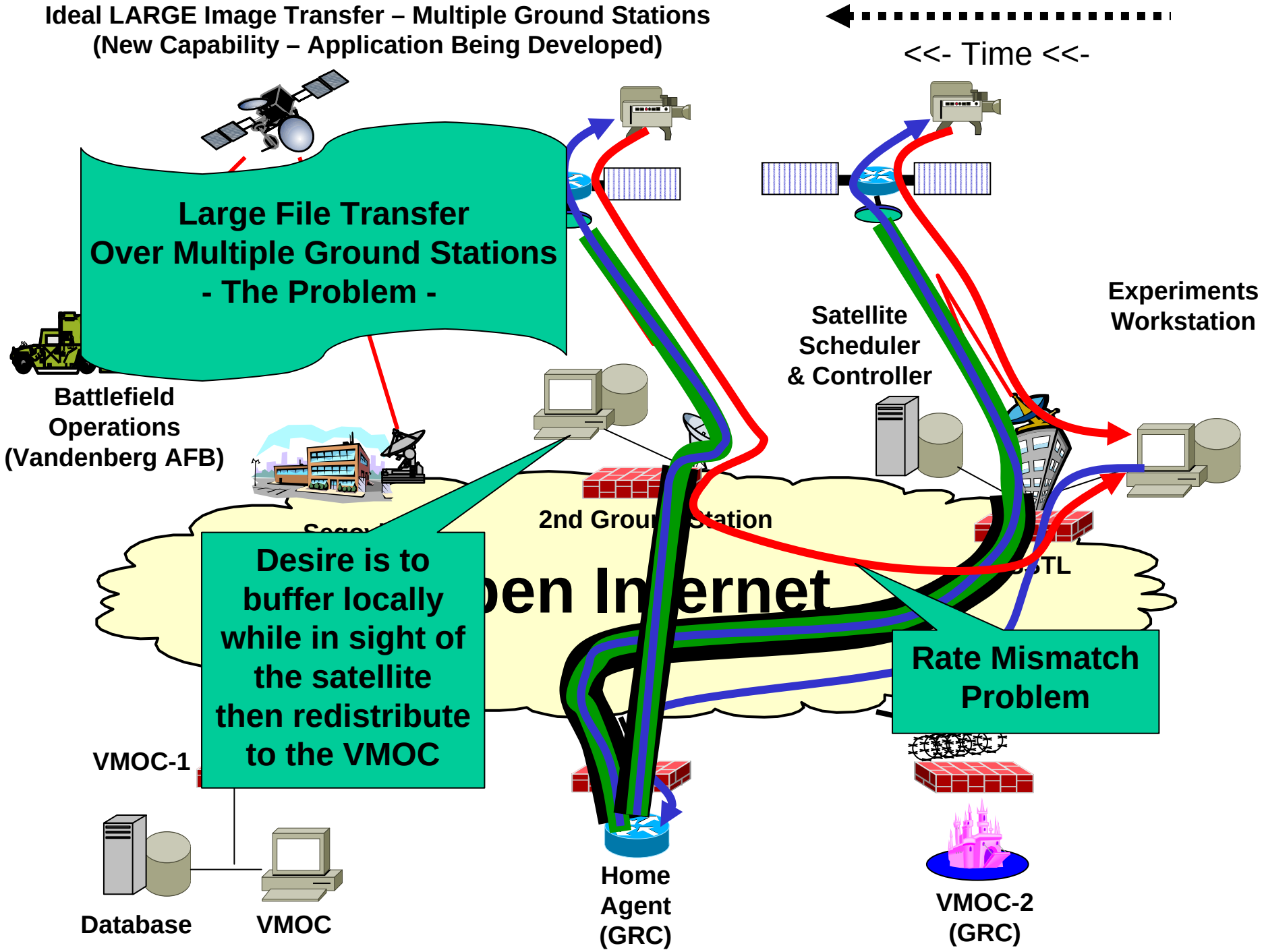
These slides have animation. As such, they are available as MS PowerPoint at:

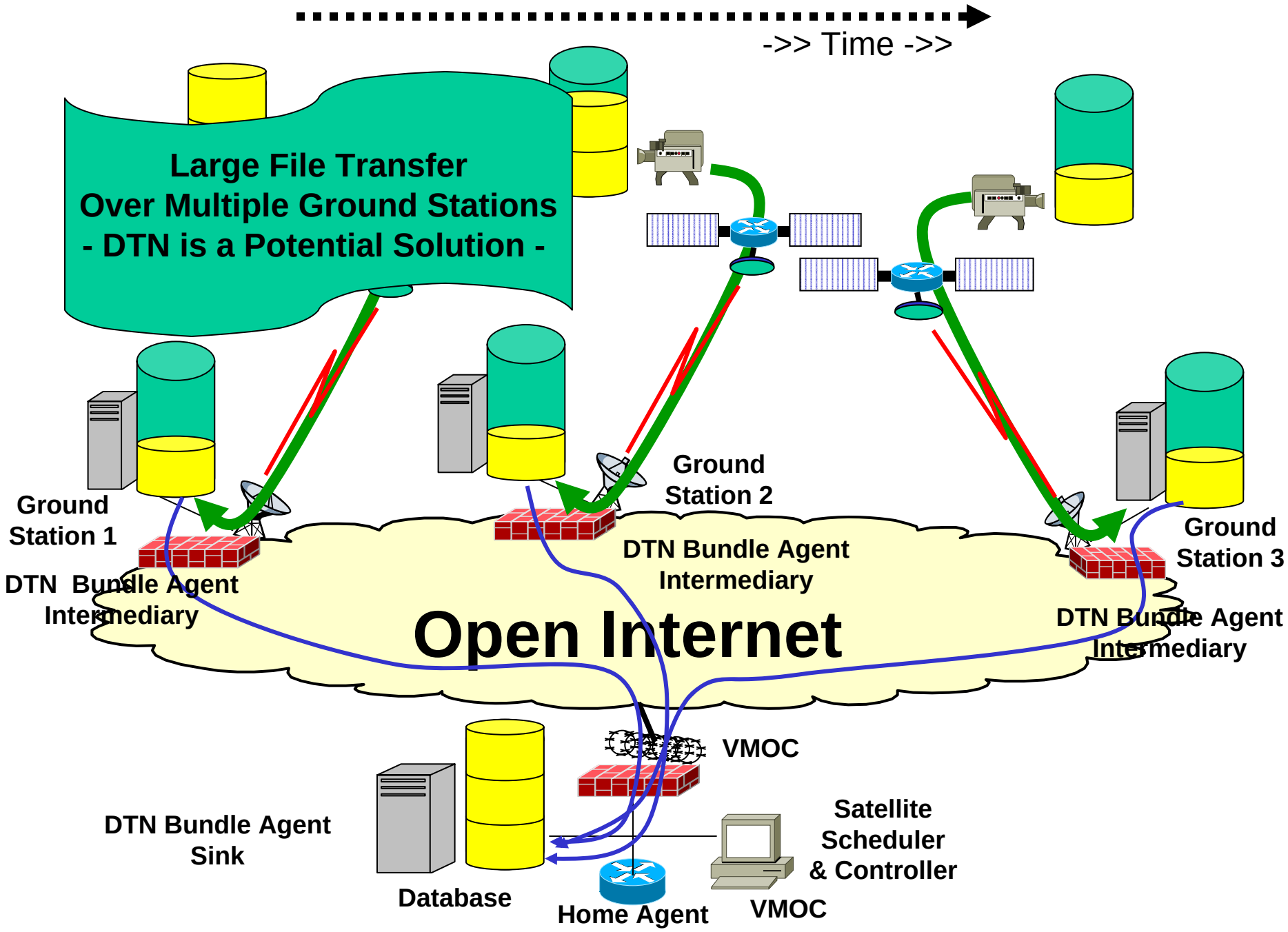
http://roland.grc.nasa.gov/~ivancic/papers_presentations/2008/IETF71_IRTF-DTN.ppt

Secure Autonomous Integrated Controller for Distributed Sensor Webs



ESTO Earth Science Technology Office


Ideal LARGE Image Transfer – Multiple Ground Stations
(New Capability – Application Being Developed)
<<- Time <<-
Large File Transfer
Over Multiple Ground Stations
- The Problem -
Battlefield
Operations
(Vandenberg AFB)
Satellite
Scheduler
& Controller
Experiments
Workstation
2nd Ground Station
Desire is to
buffer locally
while in sight of
the satellite
then redistribute
to the VMOC
Rate Mismatch
Problem
VMOC-1
Database
VMOC
Home
Agent
(GRC)
VMOC-2
(GRC)


->> Time ->>
Large File Transfer
Over Multiple Ground Stations
- DTN is a Potential Solution -
Ground
Station 1
DTN Bundle Agent
Intermediary
Ground
Station 2
DTN Bundle Agent
Intermediary
Ground
Station 3
DTN Bundle Agent
Intermediary
Open Internet
VMOC
DTN Bundle Agent
Sink
Database
Home Agent
Satellite
Scheduler
& Controller
VMOC

Combining Mobile-IP and DTN for File Upload